ESSENTIAL FOUNDATIONS FOR AN INTEROPERABLE ENVIRONMENT TOWARD REGIONAL SDIs

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Abstract: Many Spatial Data Infrastructures (SDI) have been built in different countries with the main purpose of promoting social and economic growth, protecting the environment and to manage and reduce natural disasters. Although the ultimate goal is to create an effective and efficient data sharing and application environment, the major issues that these SDIs have overcome in order to be successful are different for each country, because they have been built trying to fulfill local specific requirements and deal with different difficulties.

Interoperability and Standardization have been recognized as challenging issues for SDIs at the local level. However, when the sharing of data and geospatial services is between organizations from different countries, the problem of the interoperability and standardization become even bigger. The Infrastructure for Spatial Information in Europe (INSPIRE) is an example of a cross-countries sharing environment, where 27 countries have been making the transition from their local SDI perspective to a collaborative regional perspective.

To facilitate a solid foundation for developing a SDI, we argued that the essential components of a SDI and analyses of their interactions and relationships must be carefully examined from a standardization perspective.

As a SDI is built upon the collaboration of individual participants, this is not restricted to only technology consideration (e.g., what standards are used), but also consideration for data design, organization deployment, legal, and even cultural differences. We intend to identify the common and essential requirements for developing a SDI and propose our viewpoint about what obstacles should be removed to implement a healthy SDI. How the proposed mechanism can be used for different levels of SDI, e.g., NSDI and RSDI will also be discussed.

INTRODUCTION:

The Spatial Data Infrastructure (SDI) has been defined as a base collection of technologies, policies and institutional arrangements that facilitate the availability of and access to spatial data (SDI Cookbook, 2004). This infrastructure serves as a media for saving time and money at the moment of reuse and share spatial data among different organizations. However, to make it possible, there are several challenges that the SDI has to overcome, no

matter if the SDI is developed and maintained by a single national surveying agency or by a multiagency council. For example, heterogeneous data, lack of sharing agreement, documentation of the data available, coordination and organization, interoperability, intellectual property, culture, financial, and technological disparity are some of these challenges.

In the process of planning, implementing and maintaining a SDI, it is necessary to integrate a huge amount of resources and existing initiatives from different governmental and private agencies (services, platform, data, metadata, etc.), in such a way that they can communicate, interact and cross-reference from each other. That is why the Interoperability is a key factor for a SDI in order to allow the users to take more advantage of this integration, so they could find and use information and services quickly and efficiently. The "Interoperability" is the possibility for spatial data sets to be combined, and for services to interact, without repetitive manual intervention, in such a way that the result is coherent and the added value of the data sets and services is enhanced (INSPIRE Directive, 2007).

It is known two types of data interoperability: (1) technical interoperability, which refers to the communication and interaction between different software systems through shared interface, and (2) the semantic interoperability, which refers to standards that support the ability of people and software systems to find and use spatial data produce at different times, different purposes and maybe with different technological approach (Craglia M. et al, 2003). There are also three architectures for interoperable systems that can be applied to a SDI: (a) standardization of systems, where the internal architecture of each system is identical, including the information structure; (b) bilateral exchange, in which dedicated interfaces are required between each pair of interconnected systems; and c) standardized of the exchange language, in which the information can be exchanged between all systems via an interface of a common exchange standard (Katalin et al., 2012).

In this paper, we first analyze the essential components of a SDI, and then determine the fundamental data and services components that must be standardized during its development to achieve the interoperability. We also intend to identify the common and essential requirements for developing a SDI and propose our viewpoint about what obstacles should be removed to implement a healthy SDI. Finally, we discuss how the proposed mechanism can be used for different levels of SDI, e.g., NSDI and RSDI.

ESSENTIAL COMPONENTS OF A SDI:

The concept about the essential components of a SDI have been defined and applied with different approaches by many organizations. (Rajabifard, A. and Williamson, 2001) have mentioned examples of three different point of view related to the essential components of a National Spatial Data Infrastructure (NSDI): The first one referred to the Australian and New Zealand Land Information Council (ANZLIC, 1998), which recognizes that the essential components of a NSDI are formed of an institutional framework, technical standards, fundamental datasets, and clearing house networks; the second one is about the Federal Geographic Data Committee (FGDC) which has identified six basic building blocks, or common elements, for the implementation of the NSDI in the United States

(USA): metadata, clearinghouse, standards, framework, geospatial data, and partnerships; and the third one mentioned the Dutch Council for Real Estate Information approach of the Dutch National Geographic Information Infrastructure as a collection of policy, datasets, standards, technology (hardware, software and electronic communications) and knowledge providing a user with the geographic information needed to carry out a task. There are two main differences between these approaches: the first one identifies the components of a SDI as a first generation SDI, which pays special attention to the development of databases and is mainly coordinated by a national mapping agency, and the second corresponds to the components of a second generation SDI, which recognizes the interaction of users and data suppliers (partnerships) as a driven force for the development of a SDI (Max Craglia and Alesandro Annoni, 2007). The Figure 1 shows the scope of a national SDI:

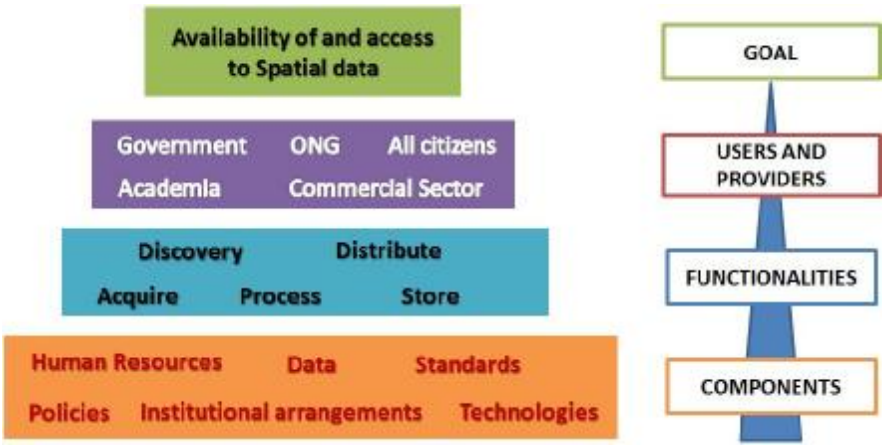

Figure 1: NSDI scope

Components interaction:

For any SDI to work properly and efficiently, its fundamental components must be able to interact and to link each other. This interaction between the SDI components has been highlighted by (Rajabifard, A. and Williamson, 2002), in which the SDI is viewed as a dynamic interaction between policy, access network, technical standards, people (including partnership) and data. This interaction is realized in two directions: (1) partnerships, representing the interaction between data users and data providers, and (2) technical components, the access network, policy and standards that users must go through to access datasets. The figure 2 shows the interaction between SDI components, in which anyone (data users thorough producers) who wish to access datasets must go through the technological components.

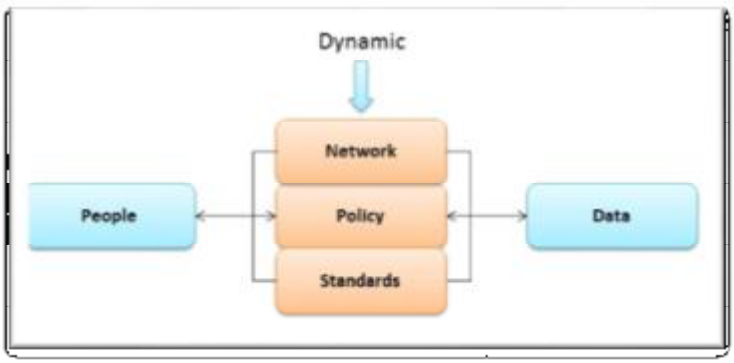

Figure 2: SDI components interaction according to (Rajabifard, A. and Williamson, 2002)

The ANZLIC approach about this interaction is based on an institutional framework, in which the fundamental datasets and the clearing house network are defined by technical standards specified in the institutional framework. The clearing house network is the means by which the fundamental datasets are made accessible to the community. The Figure 3 shows the schema of the interaction among SDI components:

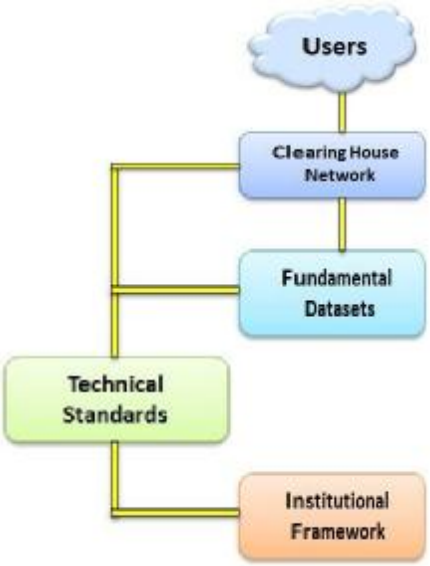

Figure 3: SDI components interaction (ANZLIC, 1998. pp.5)

CORE DATA FOR DEVELOPING A SDI

A key concern relates to the development of a SDI is to decide which data must be included into it to make it cost-effective and reduce data redundancy. A widely used solution to this problem is the creation of a common set of data (core data) that most users of a particular SDI community require for their daily GIS applications. It means that once the core data is identified, created and shared, the users do not need to spend effort to create it again. In this term, the users just need to add their own data to create thematic maps, analysis or interact (link) with an external source of data. The core data have been defined as a set of geographic information that is necessary for optimal use of most GIS applications. When this common set of spatial data is at the national or regional level, it is better known as Geospatial Framework, which provides the most common data themes geographic data users need and as well as the environment to support the development and use of these data (SDI Cookbook, 2004). Nonetheless, the data that have been included into the existing SDI initiatives varies from country to country, because this decision depends of many variables (main economic sector, participant interests, data availability, funds, etc.). At the Regional level, the data framework for the Spatial Data Infrastructure in the European Community (Inspire) includes all the data environmental analysis and impact assessment. At the National level, the FGDC in the USA designed its framework as a media to share resources, improve communications, and increase efficiency of the production and use of geographic data. The following table shows three different points of view about which data is considered to be common used or relevant for the SDI framework:

Table 1: Example of the common data used for Regional and National SDI.

Inspire (Annex I & II)	FGDC	SWEDEN
Coordinate reference systems	Geodetic Control	Geodetic reference system
Cadastral parcels	Cadastral data	Units of property rights
Orthoimagery	Orthoimagery	Orthoimagery
Elevation	Elevation	Elevation
Hydrography	Hydrography	Hydrography
Administrative units	Administrative units	Units of administration
Transport network	Transportation	Transportation
Addresses		Addresses
Land cover		Land cover
Geographic names		Buildings
Protected sites		
Geographic grid systems		
Geology		

Despite the Table 1 is just a small representation of all the SDI initiatives around the world and that each country has its own particular purpose in order to develop a SDI, it is seen there are some common data themes that have been recognized as fundamental in different countries for the SDI development. We can argue that these data themes that have been identified in the Table 1 can be the basic or ideal candidate to be standardized for the starting point of the integration and sharing of geospatial data between countries and organizations at the Regional level.

Core data interactions:

The interaction between elements of the core data themes that belong to a SDI initiative have been implemented using two main mechanisms. In the first one, which is mainly for visualization, the data themes are overlapped and the users can visualize the result of the overlapping using a geospatial web service (OGS, WMS) or a GIS application, but there is no possibility for an efficient cross-referencing or link from one data theme to another. The second mechanism achieves the data theme interaction using a unique identifier (UID) which serves as a common reference to each geographic feature within the geospatial data framework of the SD (Ordnance Survey, 2010). With the (UID), users are able to search a specific feature and find all the information related to it around the entire SDI, even if this feature is represented in one layer with a different geometry, because the feature has just a unique identifier. It is also possible that users can link their own external data with the data that belong to the SDI framework.

Figure 4 shows an example of how a unique identifier (UID) can facilitate the interaction between the core data and multiple sources in order to satisfy user's needs:

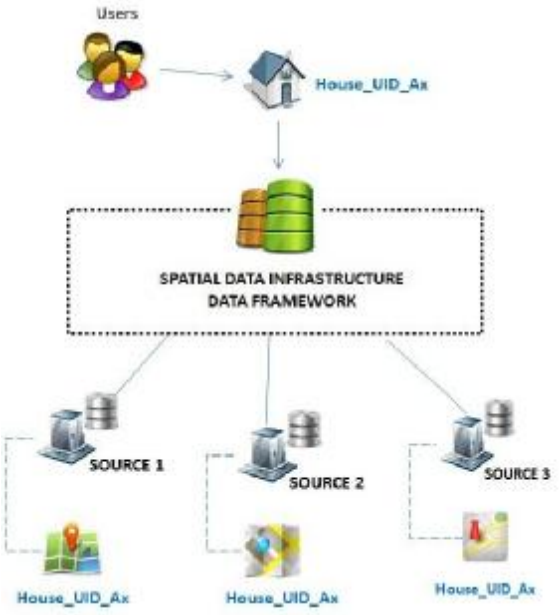

Figure 4. Spatial data interaction using a unique identifier (UID)

FUNDAMENTAL GEOSERVICES FOR A REGIONAL SDI

From a communicational perspective, the main propose of a Regional SDI is to facilitate the interaction and link between existing national and local SDI initiatives to enhance the user's availability of geospatial data and services. The geoservices have been playing a key role in the integration of spatial data from different sources in a distributed environment. Analyzing the existing Regional and national SDI experiences, we can identify a set of the minimum geoservices that can be called basic to improve the availability and use of geospatial data:

1. Discovery services:

It helps users and computer programs to search for spatial dataset and services based on their metadata record. The OGC Web Catalog Service (CSW) defines common interfaces to discover, browse, and query metadata about data and services.

2. View services:

It provides the visualization of the geospatial data. It includes functionality for display, navigate, zoom in/out, pan and display map legends and relevant metadata. The standard OGC Web Map Service (WMS) define a standard interface thorough which users can access and view maps from diverse sources though a single application.

3. Download services:

It enables copies of spatial datasets, or part of such sets, to be downloaded and, where practicable, accessed directly. The standard for this services has been structured in two parts: (a) The OGC Web Coverage Service (WCS), which

define the standard interface for interoperable access to geospatial data in a raster format, and (a) the OGC Web Feature Service (WFS), which offer access to geographic information in a vector format.

The above mentioned geoservices and the core data of each SDI initiative can be integrated trough a geoportal to provide a uniform and quick access to all the resource available in the Regional SDI. For example, the INSPIRE geoportal (http://inspire.jrc.ec.europa.eu/) in Europe provides the means to search for spatial data sets and spatial data services, and subject to access restrictions, to view spatial data sets from the EU Member States within the framework of the INSPIRE Directive. The Inspire geoportal acts as an entrance point to the European Spatial Data Infrastructure.

ESSENTIAL REQUIREMENTS FOR DEVELOPING A REGIONAL SDI

At the national and local SDI level, there are many evidences all around the world of the effectiveness of the SDI improving the availability and accessibility of geospatial data. These SDI initiatives have been designed, implemented and exploited for multiple applications, using specific data design, organization deployment, legal, and even cultural differences. However, due to this heterogeneity, it is necessary to remove some obstacles in order to create a healthy national SDI environment that make possible an interoperable migration from national SDI to the Regional SDI level. In this section, it is presented some essential requirements (technology-standard) that have to be planned ahead and to be included as a foundation for the developing of a Regional SDI.

The development of a project from a strategic point of view includes three main phases: (1) planning, (2) implementation, and (3) evaluation and control. These three phases are going to be used as a road map to address some essential questions that have to be answer before the development of a Regional SDI based on existing national and local SDIs:

Planning:

1. **What data should be included in the RSDI?** It is needed to identify a list of common data themes (core data) between organizations that they would like to share according to their national and regional interest.

2. **The identified core data can be distributed in a straightforward form?** NO, it is not a straightforward process. The data that have been collected by one organization might not fit to other organizations' specifications. It means that more discussion between these countries is necessary.

3. **What should be done to integrate the core data?** This integration can be achieved by a consensus agreement about the design of each individual theme of the core data, basically, the common attributes and its data content specifications that all the organizations must follow to create and update each element of the core data.

4. How the core data can be readable and understandable by all the organizations? To make it readable, all the organizations must create and save the core data using a standardized OpenGIS data format, (GML, ISO 19136:2007). In another hand, it is also necessary that all organizations provide a common standardized (ISO 19115:2003 and ISO 19115-2:2009) set of metadata elements (core metadata) of each theme of the core data that allow the users easily understand how the data was created, its contents and its feasibility for users' applications. The temporal and spatial representation, coordinate reference system, accuracy, attribute descriptions and units of measurements, responsible organizations, are some of the metadata elements highly desirable for the RSDI level.

Implementation:

5. Which mechanisms can be used to share the resources between organizations within the RSDI? The Internet network and the online geoservices functionalities fulfill the basic communications requirement (discovery, view and download) to link and integrate the core data and metadata that come from different organizations across the Regional SDI.

6. How to implement such sharing mechanism? At first, all the organizations must have a consensus agreement about which minimum common services (core services) they are going to use for sharing the core data and the core metadata, based on international standards. The OGC Web Map Server (WMS, ISO 19128), which provides the visualization of spatial data that might come from different server, the OGC Web Feature Service (WFS, ISO 19142:2010), which provides access and store to vector data representing geographic objects, the OGC Web Coverage Service (WCS 2.0), which provides access and store to raster data representing geographic objects and the OGC Web Catalog Service that provide the ability to publish and search collections of descriptive information (metadata) for data, services, and related information objects, are considered essential as a starting point for any SDI level. At the Regional level there might be necessary to lunch an online Geoportal to provide a centralized and integrated access point to users with all the resources and services available at the RSDI. The standard ISO 19117:2005 specification can be apply to the design of the geoportal, which defines a schema for describing the portrayal of geographic information in a form understandable by humans.

However, the development and maintenance of a RSDI could be a more complicated process, e.g. language barriers, different symbols' representation, updates of the data, and other so on. That is why until this point, the organizations involve need more discussions to validate its feasibility.

Evaluation and control:

7. What should be done to maintain the interaction between the core elements of the Regional SDI? A key strategy to keep this relationship working is to build or enhance the human capabilities of the responsible for creating and maintaining the core data, core metadata and core geoservices of the RSDI. This could be done by continuous training activities related to the latest technological, legal and organizational changes in the countries participating in the RSDI.

8. **What about the end users of the RSDI?** The end users of the RSDI also need to understand how to create interoperable data that can be linked with the data provide by the SDI or that can serve as an entry of a geoservices for further operations. This could be possible by online workshops or tutorials available for the users.

DISCUSSION

The main objective of the SDI is to enable geographic data and services to be shared and widely available in and across application domains. In order to achieve this commitment, it is basically needed at first to identify and selected: (1) the fundamental data (data framework) most users require for their applications and (2) the geoservices will make this data and analysis available to the users. But, in most of the cases, the elements of fundamental data is not ready to be shared, because it was collected and documented using a specific strategy and according to an isolated organization's needs. Disparities related to the contents and technical characteristics of the data, such as scale, attributes, coordinate reference system, format, symbols representation, accuracy, temporal representation and unique feature identifier systems, represent common obstacles for the integration of data produced and maintained by many different organizations. These disparities could be solved through an agreement between all the organizations that are responsible of the data framework about the common standards they are going to use for its collection, documentation and maintenance. This means the organizations involved have to coordinate and adjust their procedures according to the standards to make the data homogenous. The standardization agreements also cover the standards that are going to be adopted for the implementation of the geoservices and the linking mechanism for maintaining an interacting relationship between the elements of the data framework and the user of the SDI.

The advantages of the standardization in the development of the SDIs could be expressed using the street address data as a reference. Traditionally, the street address data has been used to locate people, infrastructures and events by many organizations. With a healthy SDI, users from different domains, can have the possibility to upload their street address data to an online geocoding service provided by the SDI. The geocoding service will convert this text street address data to a georeferenced point feature. At this stage, a web map service (OGC, WMS) will provide the visualization interface of the geocoding service result (point feature layer of the address location) with the core data integrated as a based map, allowing the users to create their own maps. A web feature service (OGC WFS) will also provide the possibility for the users to download the point feature layer and use it in their local application. In addition, a web processing service (OGC, WPS) can provide online analysis to add value to the users' data. two issues, the link to other domain data via street address, and what about different countries' street address systems.

In the example mentioned above, we can analyze that without the contribution of the standardization, it is not possible to take fully advantage of the existing resources and services provide by the SDI environment. For example, in order to successfully match the entry of the street address and the result of the geocoding service, a common standard street address system most must be adopted by all the participants (organizations and users) for the creation and update of the street address data.

CONCLUSIONS:

Considering the migration from the national SDIs to a Regional SDI, this paper presents a core approach as a main strategy to overcome some of the essential obstacles that the each country organizations have to overcome. We suggested a consensus agreement about which common core data, metadata and geoservices' elements must be included as a starting point. The horizontal standardization of these core elements, according the international standards, is proposed as a mechanism to achieve an effective interoperable integration. It is also highlighted the key role of a fluent communication and coordination between all the responsible organizations at the national level, as well as the importance of the improvement of the skill capabilities of the users to take fully advantages of the RSDI.

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